GRADUATE EXAMINATION, 1933.

On the pages following will be found copies of the Papers set at the 1932 Examination. Sets of these Papers can be obtained from Headquarters, price 3d. each.

The next Examination will be held on Saturday, April 22nd, 1933, but Section Committees should take early steps to ascertain that intending candidates are fully informed as to the facilities available for instruction at convenient centres in preparation for the Examination.

Success in the Examination qualifies candidates between 21 and 25 years of age for Graduateship of The Institution, but candidates outside that age may enter for the Examination, subject to the approval by the Council of the Institution of their applications.

In addition to the Sir Herbert Austin Prize, free Graduateships up to the age of 25 are awarded each year to the first five eligible candidates highest on the list of passes.

Members are requested to draw the attention of suitable apprentices and young Production Engineers to the desirability of taking the Institution Examination.

The Entrance Fee is 10s.

Candidates for Graduateship, who have passed Section C of the Associate Membership Examination, Institution of Mechanical Engineers (or any Examination exempting therefrom), are not required to take the Examination.

Copies of Rules and Syllabus of the Examination may be obtained from Headquarters or from the Hon. Secretary of any Section of the Institution.

THE INSTITUTION OF PRODUCTION ENGINEERS.

Papers set at Graduate Examination, 1932.

WORKS ORGANISATION.

SATURDAY, 2ND APRIL, 1932. (2-30 P.M.—4-0 P.M.)

Maximum Marks, 150.

Candidates are required to answer Questions 1 *and* 4 *and also* ONE *other question.*

*1. Show in diagram form the ideal staff distribution of management for a large engineering works, and explain briefly the function of each member of the staff. (60).

2. Scientific management is the forecasting and control of sales, production, costs, expenses, profit, etc. Discuss the application of these principles to an industry during : (*a*) a trade depression and (*b*) a boom in trade. (30).

3. Outline the staff and duties of the plant maintenance department of a large engineering works. How would it deal with an urgent small repair ? (30).

*4. Sketch the plan of a repetition works and indicate the routing of raw materials, sub-assembly, main-assembly, and delivery of finished articles to stores. (60).

5. Enumerate and describe the considerations involved in the selection and layout of a site for a particular engineering works. (30).

6. Describe the principles and applications of any ONE of the following transport systems :—

(*a*) Gravity conveyors and chutes.
(*b*) Power conveyors.
(*c*) Overhead Runways. (30).

7. Give a diagram of a workshop or of a large drawing office and show the location and sizes of windows and the location and candle-powers of electric lights. (30).

WORKSHOP PRACTICE AND PROCESSES.

SATURDAY 2ND APRIL, 1932. (4-0 P.M.—6-0 P.M.)

Maximum Marks, 200.

Candidates are required to answer Questions 1 *and* 2 *and also* Two *other questions.*

*1. The size of a hole, 3 inches nominal diameter, is stated as $3^{+0.0010}_{-0.0005}$, a driving fit shaft as $3^{+0.0025}_{+0.0015}$, and a running fit shaft as $3^{-0.0015}_{-0.0030}$. State the respective tolerances, interferences and clearances. Detail a combination of slip gauges equal to the size of the smallest hole.

How would the machine-setter set the tools to take full advantage of the respective tolerances? What effect has manufacturing tolerance upon factory cost? (60).

*2. Describe the machining and grinding of either (*a*) a milling cutter having angular teeth, i.e., non-relieved teeth, or (*b*) a twist drill. State all angles, the material of which the tool will be made, and what material it would be used upon, giving the speed and feed that you would expect from it on a given type of machine. (60).

3. Calculate the machining time on a mild steel forging, Fig. 1: turned to 7 inches diameter, length 2 inches; faced between diameters 7 inches and 3 inches; and bored to a diameter of 3 inches through a length of 5 inches. Assume one roughing cut and one finishing cut in each case, and use suitable speeds and feeds. (40).

4. Sketch and dimension a simple article which includes a modification to facilitate production. State your reasons for the modification. (40).

5. State briefly the principles underlying the use and design of jigs and fixtures. Sketch and describe a fixture or jig for any ONE of the following, and also give a rough, dimensioned sketch of the component.

(*a*) Machining the external surfaces of pistons.
(*b*) Gang milling the bosses of connecting rods.
(*c*) Assembling roofs of saloon bodies.
(*d*) Lathe front apron. (40).

6. Enumerate the kinds of data respecting the machine tools in a factory which the planning department should possess.

The highest and lowest spindle-speeds of a machine having 18 different speeds are respectively 2,230 and 100 revolutions per minute. Calculate the 16 intermediate speeds. (40).

7. Describe the sequence of assembly of any ONE of the following: a machine tool, a horizontal oil engine, a cycle, or a motor car body. (40).

8. Discuss the relative merits and de-merits of Multi-Purpose and Single Purpose Machines, after having carefully defined what you mean by each type with examples. (40).

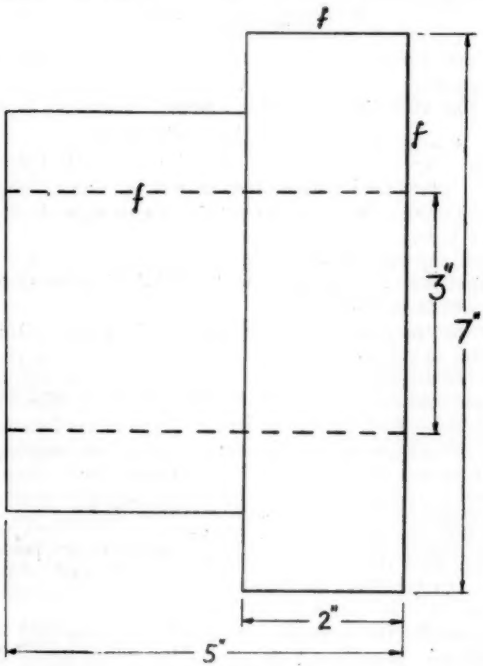

FIG. 1.

9. A firm uses a certain standard component at the rate of 80 per month. The costs of direct labour (operator) and material per component are respectively sevenpence and sixpence. The direct labour cost for each setting-up of the machine is 8/4. Oncost is 100 per cent. on direct labour cost in each case, and the rate charged for loss of interest and depreciation on stock in store is 10 per cent. Assume that the minimum stock is 40 components. Calculate the economic number of components that should be manufactured after each set-up. (40).

INTERVAL 6-0 P.M.—6-30 P.M.

ESSAY AND INDUSTRIAL ECONOMICS.

SATURDAY, 2ND APRIL, 1931. (6-30 P.M.—8-30 P.M.)

PART I.

Essay. Time allowed—half hour. (50).

Select *one* only of the following four subjects :

(*a*) Apprenticeship training as an essential grounding for the Production Engineer.

(*b*) Describe time study, and indicate how it can be used as an aid to rate-fixing.

(*c*) Rationalization.

(*d*) The gold standard and its relation to the Production Engineer.

Industrial Economics. Time allowed—1½ hours. Maximum Marks : 150.

Candidates are required to answer Questions 1 *and* 7 *and also* ONE *other question.*

*1. Describe the functions of fixed capital and floating capital in industry. How can their productivity be increased ?

A company issued the following fully-paid shares :

30,000 ordinary shares at 5/- each ;
4,500 preference shares at £1 each, 7 per cent. per annum ;
3,000 cumulative preference shares at £1 each, 6 per cent. per annum.

At the end of the first year of trading a profit of £150 was available for distribution ; in the second year, £600 ; and in the third year, £1,700. Tabulate the percentage rates of dividend which could be paid to each type of share in each year. Why is it not policy to distribute the whole of the profits made in one year ? (60).

2. A distributor sold a motor car, list price £200, on the deferred payment system for £50 cash and the balance in twelve instalments of £13 per month. The distributor's commission from the manufacturer was 15 per cent. of the list price. To pay the manufacturer the distributor borrowed the necessary amount from a credit company at the rate of 6 per cent. per annum on the balance outstanding at the end of each month, i.e., the distributor repays at the rate of £13 per month and his final payment settles the debt exactly. Determine the distributor's profit. (30).

3. Discuss the utility of graphical methods to estimators and salesmen.

The following data refer to parallel vices :—

Weight, lb.	15	30	50	67	99	123	164	197
Price, £ ...	1-8-6	1-17-6	2-0-0	3-6-0	4-0-0	4-19-6	6-0-0	7-0-6

Determine a formula connecting weight and price, and give a revised price list. State which prices should be investigated. (30).

4. The output of a machine is 10 pieces per hour, and the operator's time rate is 1/3 per hour. Calculate the job rate per piece so that this operator may earn a bonus of 33⅓ per cent. on (*a*) piece work, (*b*) the Rowan premium system, and (*c*) the Halsey-Weir 50 per cent. premium system. (30).

5. Complete the following cost statement of a job and determine the factory cost of the job.

Machine.				Direct Labour £ s. d.
M/c. No.	Rate : pence per hour.	Hours	Machine Charge £ s. d.	
5	3.5	10		6 10
11	5.0	4		3 4
17	6.5	7		9 11
Totals ...				

Cost of raw materials, 8/9. Departmental expense rate, 0.83 penny per hour. General expense rate, 0.67 penny per hour. (30).

6. State and explain the economic factors and laws affecting sales and production. How can a manufacturer determine the economic output of his factory for a given market ? (30).

*7. What particulars should be included in a specification controlling the purchase of an electric motor and controller gear and how should they be set out ?

Describe the organization for controlling the standard of purchases. (60).

8. Give particulars of machinery to bring together employers and employees in any industry for discussing trade disputes, and describe an example of its effectiveness. (30).

RANDOM THOUGHTS ON OVERHEADS.

Paper presented to the Institution, Luton, Bedford, and District Section, by W. G. Groocock, M.I.P.E.

Introduction.

WHEN your committee first asked me to give you a paper and suggested the subject "Overheads and Production," I almost made up my mind to turn their suggestion down because I felt that I knew little of this question of overheads and its connection with production. On thinking the matter over, however, I definitely came to the conclusion that it might be an advantage in compiling a paper of this description not to know too much of the subject matter itself, but to deal with it rather from the angle of collected facts analysed along certain lines with the definite object of providing a good discussion.

My remarks to-night are addressed in particular to those production engineers who have little opportunity of studying either costs or overheads. Much of what I shall say may be considered elementary, but it is an understanding of the elementary things that leads us up to a study—and probably helps to a solution of—the higher problems. You will see, therefore, from my opening remarks that firstly I know little of the subject about which I am going to talk, and secondly, I am going to talk about it in such a way that I hope to draw some of you into a discussion of the points I shall raise in giving you my "Random thoughts on Overheads."

All present will, I think, agree that there never was a time in the history of engineering when economic manufacture was more important than it is now. All will, I believe, agree that economic manufacture cannot be carried out unless there is an efficient system for ascertaining costs. The moment we begin to think of the cost of manufacture, we then come into that side of the problem which concerns itself with overheads. If we look at a "made up" shop cost of any piece of apparatus we find that the cost itself is built up of three main items, namely, material, labour and overheads. It is relatively easy to find out the cost of material and also the cost of labour required to make a piece of mechanism. It is less easy, however, and sometimes quite complicated to get a true perspective of what is a reasonable overhead charge to apply to that particular piece of apparatus, and the best means for absorbing these charges into the cost.

February 10th.

What are Overheads ?

The first question we ought to ask ourselves is : What are overheads ? This is really a difficult question to answer, and I venture to assert that if that question is put to six different managers you may get six separate answers ; answers that are widely different in their essentials. I believe, however, that in those six answers you would get one line of thought with which we can all agree, and that is, that overheads are the bane of the life of any works manager, particularly at the present time. Knowing that there is this type of variation of thought in what overheads are supposed to be, I will give you my version of what I mean when I speak of overheads.

During the past six months we, as a nation, have been passing through a somewhat critical time, and although it is not yet admitted that this critical period has been due to excessive overheads, there is not the slightest doubt that nationally we are, and have been for a long time, suffering from a difficulty in balancing our budget, and this difficulty has been due to the fact that our overhead expenses have been far too high. It is not my intention to-night to attempt to point out in what respect our national overheads have been excessive. I merely mention it to emphasise the fact that nations, like business men, do have to keep a balance between their overhead expenses and their possible income from whatever source such income be derived.

Now let me bring this down to the language of the shop. In running a works of any description, whether it be small or large, we are faced with a whole series of expenses ; rent, rates, taxes, insurances, depreciation, salaries for supervision, wages for expense labour, and of course, all the expense material required for the efficient running of our factory. These I will call our expense burden.

Expense Burden.

From what I have said it will be seen that we have in every factory a definite expense burden ; a burden which does not vary directly with the amount of work going through because many of the charges, making up that expense, have no connection at all with the quantity of product being manufactured. The problem we have to consider, therefore, is how to allocate, or split up the expense burden as between the various pieces of apparatus being made, and in what way it shall be entered on to the cost sheet. Many systems are in use and there does not appear to be any general agreement as to the best system to use. The allocation of an expense burden to the costs in a factory is well worthy of considerable study, and indeed is a large enough subject to be put over to a central research department with a view to finding out if there is any definite best way for charging our overhead expenses on to the apparatus that we make.

In general it is quite an abstract problem, and before anyone

can say which is the most suitable system for applying overheads, they would have to consider a very large number of factors. They would, I fear, also meet with considerable difficulties inasmuch that there are many people to-day who are quite certain that the system they use is the best. Personally, while I have a preference for one particular system, my preference is built up round the particular type of work that I am doing. Under other conditions I can well imagine that other systems might be better, but in my view there are really only two main systems to consider, namely, to apply the expense burden as a percentage on the direct labour, or to work along another system which is known as the machine hour rate system.

Spreading the Burden.

The common method of recovering these expenses is to spread them pro rata on to the work that is passing through the works. The distribution, or allocation, of this overhead expense is performed in many different ways. For instance, the expense burden is often spread over the whole product by adding to the cost, a sum of money equal to the direct labour multiplied by a percentage representing the expense or establishment charge. Another way is to apply a machine rate which means that all machines, presses, benches, etc., are rated, and this hourly rate is used instead of a percentage on labour. There are many ways of spreading the expense burden of a factory, but fundamentally, they are all the same. Their object is to charge on to the work going through the factory a proper proportion of our overhead expenses.

Now so long as the factory is carrying a normal load, this normal load will also carry its normal share of expense, but many of our expenses in this connection have no reference whatever to the amount of work going through the shop, and consequently there is likely to be serious difficulty in getting rid of this expense burden as and when the load on the shop becomes lower than a certain point.

Whether we use the percentage basis or the machine rate as a means for spreading our expense burden on to our cost, there is always a danger of such percentages, or such machine rate, being regarded as final. There is no such thing as finality in this respect. The moment you begin to alter the conditions in your establishment, then there is a probability that you may have to alter either your percentage basis, or your machine rate. It is sometimes argued that high machine rates, or a high percentage basis is a sign of inefficiency in the shop where it is practised. This is an entirely false view. Under many circumstances high machine rates and high percentage basis may be definitely a sign of efficiency. To make my point a little more clear, may I refer to the real issue.

The Real Issue.

There is one point that we must never overlook when we are dealing with costs and the application of overheads to same, and that is, that the vital factor so far as we are concerned, and so far as our customer is concerned, is the ultimate price of the article to the customer. It is easy to conceive a case where the labour is so inefficient and the labour charges are so high that a low overhead percentage will recover more than sufficient of our expense burden to wipe off our total in a year, but in such cases it is usually found, or it may be found, that the price of the article is non-competitive and we cannot sell it. On the other hand there are numerous cases where the labour charge is so low that even with a high percentage basis for our overhead, or a high machine rate, whichever we may be using, the total cost is still such as to allow us to compete with others and sell the article that we are making.

Factory Load and Expense Burden.

Overheads are something which seem to bear very little definite relationship to the amount of work going through any shop. There is, of course, a connection, but too often there are so many standing charges that have no connection at all with the product going through, that the difference between full load and half load does not mean that there can be any serious reduction in the overhead expenses.

If you were to examine a chart built up of the factory expenses of any given factory, you would find that they all bear a very close resemblance to each other, that is, the form of the curve will be almost identical, but the magnitude of the sum involved will, of course, be different. One of the most interesting curves to study is a curve built up to cover a factory whose load condition might possibly vary from .5 full load to full load. If such a chart be constructed synthetically we should have—starting from the bottom and building up on to each other—a series of parallel lines, that is, the burden they represent has no reference whatever to the amount of work going through the shops. Among these charges we should have—rent, rates, taxes, insurances, and of course, depreciation. The sum total of these expenses may often be such that when the factory is only half loaded these charges represent a sum of money equal to between 70 and 100 per cent. on the direct labour being used. The point I want to emphasise here is that these charges are almost entirely outside the control of the factory manager.

The Components of Our Overheads.

It is, I think, advisable to point out that the overheads I am considering are those of the factory only—the portion that we as production men are supposed to be responsible for. Factory expenses can be definitely divided into three groups.

GROUP 1. This group covers those expenses that do not vary with the factory load. In this group we have: rent, rates, taxes, insurance, and depreciation, etc.

GROUP 2. The expenses in this group do vary slightly with the load. They are salaries of factory staff, both supervisory and clerical, and in this group also I would place "heat" and "light," and maintenance of property.

GROUP 3. The expenses which come into this group have some definite relationship with the amount of work being done, that is, this group of expenses varies with the load on the factory. They are: indirect labour (not covered in Group 2), power, maintenance of plant, supplies such as small tools, lubricants, gas, etc., also all other expense material.

It is my considered opinion that the man in charge of production has no responsibility with regard to the first group. They are fixed and outside his control, and if they are too heavy for the load on the factory, it is up to the directorate to look into the question and, if necessary, change their policy so as to ease this side of the factory burden. In the second and third groups there are a number of expenses which must receive constant attention from us to see that they are kept down to a minimum consistent with efficiency.

At the beginning I stated that my main idea in giving this paper was to create discussion, and for this purpose I propose now to review a few items that affect the expenses covered by Groups 2 and 3, with a view to exploring some of the factors which prevent certain of these expenses from following the fall of our direct labour when our factory load falls below its normal point.

Vital Factors.

While there are many factors which may affect our overheads there are in my opinion four that may be considered as of primary importance. These I will discuss under the headings of :—

(a) Indefiniteness of Factory Load.
(b) The Influence of Quantity Manufacture.
(c) Quality of Product.
(d) Type of Organisation.

Indefiniteness of Load.

If I were asked to give an opinion as to which is the factor that has the greatest effect when overheads are higher than they should be in a works, I would say without hesitation that assuming that the management is alive and is trying, then the greatest deterring factor that prevents them lowering their overheads is indefiniteness as regards the future.

Many factory managers are in the dark as to their possible load. It seems incredible that to-day there should be any attempt at

manufacture of any type of commodity unless such attempt was preceded by a sales budget, and yet too often this is exactly what is taking place. I am not referring in particular to trades that are seasonal, because in such trades we naturally expect to have wide variations both in the numbers employed and the hours of work. The importance of capital tie-up demands that as far as possible seasonal trades should be followed, but even so when we have a live selling force, then they should have some knowledge beforehand of the load that is coming on to the factories, and if this is passed on to the factory manager, then he can save considerable sums of money over those other cases where the management gets no knowledge of the load until it is upon him. One or two week's notice of a coming load can save considerable sums of money, but with a sales force that has its finger on the pulse of the countries' requirements, then those three or four weeks can quite easily become three or four months, and such notice would have a wonderful effect on our overhead expenses.

Fluctuation of Orders.

The question of our overhead expenses is relatively a simple one when we are working with a full load on our factory. When, however, we are working only partially loaded, then the question becomes more serious as our output drops below the full load point. The ideal, as stated before, would be for our overhead expenses to fall down in the same ratio as our output, but since so many of our overhead charges are independent of our load, then clearly as these cannot be altered we must pay our major attention to those factors where there ought to be a drop in the indirect expense in some sort of proportion to the drop of our direct labour.

If we take the case of a factory working on full load which suddenly finds its load drop until it reaches a point approximately half load, we shall find first of all that there is a definite lag in following this drop of output down the scale, and a wise management will do all in its power to make this lag as short as possible, but however strong the intention there are certain factors which are operating all the time and tending to make the lag persist, and these are, generally speaking, due to a lack of knowledge of what is to take place next. When the drop in output starts we would normally go after our indirect expense, particularly our indirect labour, and we should take out as rapidly as we possibly could, that section of our indirect labour which we could replace fairly easily if we wanted to at a later date.

With regard to the skilled sections of our indirect labour, such as our tool room force and, of course, our staff, we should be more careful before dispensing with such labour as we may have difficulty in getting it back should our business revive. It is here that the maximum lag will occur, and it is in such cases that our sales departments can be of extreme assistance if they will give us as

accurate an estimate as possible of the output from us required during the next three to six months.

With a clear cut estimate as to what is required from the factory (in other words, an output budget) the works manager has far less trouble with his overheads than he does in those cases where he gets no assistance from his sales organisation.

The Influence of Quantity Manufacture.

There are, as I said before, many factors that influence our overhead expenses, and some of these factors tend to increase our overhead expenses, whilst others may have the opposite effect. Let me now discuss one which I feel will almost invariably tend to decrease our overhead expenses, and that is, the quantity factor. If you have ever been in a factory and seen it grow from the making of small numbers of various kinds of articles until it arrived at a stage where it began to manufacture larger numbers of fewer types, you will know what I mean about the influence of quantity on overhead expenses. You will have a much clearer idea still if you have ever seen that same factory grow until it was putting large quantities of only one article through the works.

The normal procedure of these various stages is undoubtedly along the same direction whatever the product that is being made. When the quantities of types are reduced and the number going through the shop is increased, you will find that there is a definite dropping of the clerical personnel required to put the work through the shop. Further, when this is altered again to standard production of one type of product moving continuously through the shop, you might again expect to see that there would be a still further drop in the clerical personnel, but this is not usually the case. This second move, which of necessity is coupled with mechanical devices for moving the work from place to place, quite obviously cuts out a considerable amount of shop labour. It does, of course, mean capital outlay, but it is the type of capital outlay which is easy to justify because the savings made in one or two years are quite often sufficient to pay for the installation of the moving platforms, etc. On the other hand this type of manufacture calls for precision in timing. It is absolutely necessary to know at all times the state of the various components that go to make up our article, and we must time these various parts so that they reach their appointed place in time to be assembled into a complete unit. This means, of course, almost invariably that for this type of manufacture, while we do reduce our force of shop labour, we may have to, and almost invariably do, increase our supervisory and clerical personnel.

At this point it might be well to briefly refer to a theory which from time to time gets a measure of support, and that is that we ought to maintain a certain ratio between our indirect and our direct labour.

Ratio of Indirect to Direct.

There is a line of thought that seems to suggest that our ratio of indirect expense to direct labour should always be a certain definite percentage. It is true that given a set of conditions that have been stabilised we are able, under such conditions, to maintain a ratio between our indirect expense and our direct labour, which ratio, if taken over definite periods, remains fairly constant. But it is true also that this ratio is very sensitive to changes in other directions. The ratio is sensitive to change of design ; it is also sensitive to multiplication of type ; and quite obviously too, it is sensitive to any rearrangement in the type of apparatus that is being made.

There is also a line of thought which suggests that there may be a definite ratio between our indirect labour and our direct labour. Here again I would emphasise that there are many factors which can change such ratios materially. Quite clearly, this consideration is dependent wholly and solely on whether we change our methods in the shop or not. We may, under a certain set of conditions, be very efficient with regard to our indirect labour, and yet, when we make certain changes we may take a lot of this labour away and be still more efficient than we were before. This is quickly apparent if we make certain changes in our method of running the work through the shop, and provide labour saving appliances for moving the work from point to point. For instance, we may be putting our work through in small batches. Our machinery may be grouped as to type, that is, lathes in one position, milling machines in another, boring machines in another, and so on. In that case, the best we can do is to provide labour for moving the work from one operation to the next, but later on our output of a particular type may be such that we shall find it advantageous to alter our group arrangement of machines into a line arrangement where the work progresses in its natural sequence, and the machines are placed in such a way that from first to last operation the work progresses in a straight or continuous line. In such a case a simple roller conveyor may be the means of passing the work from one operation to the next, and thus by regrouping the machines and by providing the conveyor, we practically cut out all the cost of handling the material between operations.

It will be seen, therefore, that our ratio of indirect to direct does depend quite materially on the quantity of work going through, because this will be the determining factor as to the type of layout in our shop.

Quality of Product.

Now there is another influence that tends quite seriously to burden our overheads, and that is the influence of quality.

Let us take the case of a company making a certain series of standard article in moderate numbers and of moderate quality.

They have for years been running along at a standard rate of expenses. They have spent only a small amount on their tool room and as little as possible on their inspection. Then the directors decide on—or are forced to adopt—a higher quality of product. This means at once an increased inspection force and an increased number of tools and gauges to ensure that such quality has a reasonable chance of being achieved. Quite clearly, one cannot jump from a moderate quality to a high quality in the course of a month or two, but however long it takes, it may be taken as certain that the mere fact that the quality is being improved is bound to increase the overhead expenses unless there is some compensating advantage. One of the factors that might keep down our overhead expenses when we improve our quality would possibly be in a case where at the same time that we were attempting to improve our quality we were also making other changes which would lessen the number of types and increase the number going through the shop. These two factors would tend to off-set our expenditure in obtaining quality, but the fact still remains that any change of quality that we make for the better must of necessity add something to our expenses, and as a consequence increase our overhead burden, unless such change would bring us "increased sales" or some other compensating advantage.

Type of Organisation.

Another factor that may, and often does, influence our overhead expenses, is the type of organisation which we are using. We are often told, or we often hear, of establishments who are running so cheaply that their overhead expense burden does not amount to, shall I say, 75 per cent. of the direct labour. Such establishments may or may not be economical, but almost invariably when we examine their personnel we find that they have a very simple organisation, and that paper work, and indeed all the work of the organisation is cut down to its simplest form. You and I have seen this type of organisation drop out simply because it was inefficient. Too often their low overhead percentage was due to an extremely high labour cost coupled with an inefficient organisation generally behind, and this inefficiency resulted in the way that it usually does, namely, such organisations drop out.

At the opposite end of the scale from this simple organisation we have the complicated organisation which attaches itself to some of our very large companies; companies that have works in various parts and an organisation which is centralised at Headquarters to take care of a number of functions, the idea being that it is cheaper when it is centralised. Looking round the room I see several men here who will agree with me that it does not do to jump to the conclusion that centralisation in an organisation means cheapness.

Almost invariably such centralisation leads to stagnation of mentality; to the attitude of mind that says and thinks that what we did yesterday was right; to the attitude of mind which believes not that the various factories are earning the dividends for their group, but that the dividends are earned by the stagnant brains at Headquarters.

When stated in this way one can see that the large organisation and the small organisation both start off with definite severe handicaps, and examined closely we find that these handicaps are purely mental.

There is no reason at all why the small works should not have a high overhead charge and be efficient; there is no reason either why the large organisation should not have some sort of centralised control which should also be efficient, but the fact does remain that almost invariably at these two ends of the scale there is inefficiency with regard to overhead burdens. You may have an overhead that is far too heavy although it only amounts to 75 per cent. of the direct labour. You may have also a centralised authority which is far too costly although as a percentage it may not appear too high. In between these two extremes there is ample room for efficient organisation.

The Burden of Indirect Labour.

The one factor that is of paramount importance when dealing with our expense burden is to see that while all the component parts of our organisation are functioning efficiently, that such efficiency is achieved with a minimum of expenditure. Many firms to-day are suffering from the fact that during a period when trade was good they built up a system and an organisation that was unduly expensive and probably—if closely examined—none too efficient.

Whether we consider our organisation is efficient or not, we must always have it under review with a view to keeping it up to date. As production men we are never satisfied with our methods of production; always we are striving for cheaper and more efficient means for doing the work, and I want to emphasise the need for this type of mentality in dealing with that side of our organisation which constitutes one of the major burdens to our factory expense, viz: indirect labour. This section of our overheads must be under constant supervision. Roughly, we can divide it into five groups, viz:

(1) Staff (Supervisory and clerical).
(2) Inspection.
(3) Tool Room Force.
(4) Maintenance Section.
(5) Shop labourers, Cranemen, etc.

Obviously, this side of our subject can only be dealt with in a

general manner, but there are certain points I wish to raise with a view to creating a discussion, and these I will briefly deal with in the order given.

Staff.

In a modern factory the staff is almost invariably built up round a certain routine, and the numbers required to work this routine are somewhat like the wheels of a clock. That is, if we take some away the clock will stop unless we re-design it. From this you will see that the number of staff is a function of the routine. A curious fact in this connection is that when work expands in a particular factory to nearly double of what it was previously, it has been found that little extra supervision has been necessary. Generally speaking, it only means the addition of a few juniors on the clerical side. When we come to examine our position with regard to our staff we cannot separate them from the routine they are supposed to carry out, and we ought to give very special attention to the routine to see whether it can be simplified and thus allow us to reduce the personnel required to work it.

Is an Inspection Department Necessary?

In examining our indirect labour we shall probably find that a goodly sum of money is devoted each week to our inspection department, and the questions that naturally arise in our mind are first—Is an inspection department necessary? and secondly—If so, can the expenditure of such a department be reduced without any sacrifice in quality?

Dealing first with the question of whether we can do without an inspection department, I can say quite definitely that there are few, if any, engineering works in this country that can afford to do without an inspection department of some kind or other. Such a department is a tool of management. It is the measuring stick whereby the manager or management know whether they are giving to their customer the quality of article for which he is paying. To ensure that the quality is up to the standard fixed by the management, there must be both inspection of material used, and the more or less critical inspection of the product made both in detail and the final apparatus. It is true that the very small engineering works may get along without an orthodox inspection department, but when such is the case there is still an inspection, and quite often this inspection is delegated to the foreman, or foremen, who, acting for the manager, determine that the work is up to the standard required. There are inherent drawbacks to this form of inspection. It is asking too much of human nature to expect that the foreman himself shall be critical of the product he is turning out, and almost invariably when the inspection is in the hands of the foreman, then

there is a great probability that the standard of workmanship will be lowered. The management will apply pressure to the foreman with a view to producing the work more cheaply, and this inevitably will tend to a lowering of the standard of quality.

When we come to the question of whether or not we can lower the cost of our inspection department, we are faced with a much more difficult proposition to decide. The tendency of all inspection departments that are not constantly under review is to be super critical on points that probably are not important. They, like the rest of the human beings, are desirous of being 100 per cent. right, and with this in view will quite often insist upon a 100 per cent. inspection. It is at this point that the management can step in and decide, in consultation with the chief inspector, just those points where a 100 per cent. inspection may be necessary. There are many places where a percentage inspection ensures practically the same quality of output as if all the pieces were examined. On the other hand there are other points where 100 per cent. inspection appears to be necessary, but such cases should be periodically considered with a view to seeing whether experience has demonstrated that the numbers to be inspected can be reduced.

There are further cases, particularly in a machine shop, where periodic inspection of the pieces coming off certain machines will ensure that the standard is maintained. This is particularly true where there is a tooling set-up to do a certain job, and in such cases, whenever there is a change of tools, then the inspection should examine the last few that come off before the change, and the first few that are brought off after the change has been made. It is by working along these lines that the manager, through his chief inspector, or his deputy, whoever he may be, can keep his inspection costs down to a minimum.

The Importance of High Grade Supervision.

Of late years there has been a tendency of thought towards weakening the importance of supervision, particularly that section known as foremen. In repetition works the foreman's duties are often taken over by the planning-department, and the foreman himself is little more than a progress clerk. While this may be the correct procedure in the producing departments, modern practice demands a higher standard of foremanship from those in charge of the service departments, such as the tool room and millwrights' section. Here only the best type of foremanship can give us the service we require and at the same time keep the cost of such service down to a figure which will not inflate our overhead expenses. There is no economy in having a cheap grade of foreman. He is too expensive.

The Tool Room Force.

Dealing now with the tool room force, the ideal in a factory making a standardised product would be to only have a skeleton force in the tool room for the repair of tools and for the making of odd bits of equipment and jigs which are wanted urgently, and to purchase the remainder of tools and jigs from outside suppliers. This seems on the face of it to be the most economical way of dealing with this side of our subject, but almost invariably, owing to difficulty with jigs and tools that have been made outside, also owing to difficulty in having to make changes rapidly, which changes the outside supplier can rarely do in the time necessary, the tool room gradually increases in size, and to keep an even force in the tool room it has, in the past, been found necessary and economical to make a certain number of what might be called standard tools. While I have every sympathy with the various factors that lead up to this condition, it is in itself a dangerous condition unless it is most carefully watched. For the tool room foreman who knows his business and will definitely keep such work down to a minimum, it is the right thing to do, but unless the management themselves watch it very closely, they will find that many tools are made which can be bought outside, not only cheaper, but better. To keep this side of our force down then there is no royal road to success except a constant supervision by the management over what is being done.

Maintenance Section.

In this section we have our millwrighting force who look after and repair any machines that go out of action. It may also include a section devoted to looking after the buildings, keeping them in repair, both as to roofs and walls, also the upkeep of our roads, if any.

Dealing first with the millwrighting force, this again should be watched very closely by the management. It may be more economical sometimes to take a machine out of action and repair it before it is broken down, than to leave it until it does actually break down. It is a question which ought to be decided on its merits, but too often it is decided on the magnitude of our overhead burden rather than on the most suitable way of dealing with any specific case. Quite often, however, a management, by the tabulation of repairs, etc., soon builds up information which shows them whether a machine is worth more repair, or whether it has arrived at that state where it should be scrapped, that is, more economical to scrap it than to repair it further.

Let us take the case of the machine shop of a factory only working at half load. Under such conditions, there would not be so many repairs to machinery required as when the shop was working to

capacity. As a consequence we ought to be able to dispense with some of our repair force. What usually happens, of course, is that during these slack periods the machine shop foreman wishes to have some of his machines thoroughly overhauled and, therefore, unless the management step in, the maintenance labour does not fall proportionately to the falling off in our product.

In the case of maintenance of buildings, etc., this varies very little whether we are working full or half load.

Shop Labourers, etc.

When we come to deal with the type of indirect labour such as shop labourers, cranemen, etc., we find that this class of labour can be decreased as the work in the factory falls off, but even here it is not possible to reduce our labour in proportion to the falling off of our product. For instance, there is a permanent force required to keep the shop clean apart from those required to move the work about, and most of this permanent force would be wanted whether the works were slack or busy. With regard to the section required for moving about the work, quite often when work is slack there is definitely more moving about of the work than when there is a full load. This will be easily understood by most of you, since you know that in the bare factory—that is when only one half of your machines are manned—you will quite often shift your work about, whereas, if the whole of your machines were manned you would probably get your work through in a straight line fashion. Here again you will see that it is not possible to bring down even your shop labourers proportionately to the drop in your product.

These are facts which I feel are not thoroughly understood, and I have mentioned my view on this matter so that we can have a discussion to-night, not only to clarify my own views, but with a view to getting some general opinion as to whether it is possible to run an establishment economically at full load and half load, and in doing so extract from you what kind of proportion we might expect to have in the various sections of our expenses that go to make up our total overhead.

Payment of Indirect Labour.

Many works managers to-day are turning over in their own minds the question of—" Can we cut down our indirect labour if we pay as much attention to it as we have in the past to our direct labour" ? This is a question that is worthy of considerable thought. It is a question on which outsiders can only generalise, but although that is the case, I would like to draw attention to one or two points which seem to me to be worthy of special attention.

When we ask ourselves the question of " if we paid as much attention to our indirect labour as to our direct labour," we have

in mind obviously the question of systems of payment by results, or alternatively, of so organising the work that each operator must of necessity do his or her work in the specified time, otherwise there is a lag in the procession which is instantly apparent. I do not propose to deal with this latter phrase as it almost automatically takes care of itself as and when the output warrants that kind of production. I want at the moment only to deal with that type of works where the direct labour is paid under some system of payment by results such as piecework, or a bonus scheme.

A man who is turning a shaft, for instance, has a specified sum of money for doing the work, and for his own benefit, does such work in a reasonable time, but the man who is moving these shafts from the turner to the machine for the next operation, has no such incentive and can lose considerable time in such transportation unless the supervision is very keen and, of necessity, has time to see that he does it as quickly as possible. Many schemes have been put into operation for awarding the shop labourers who transport work from place to place, such sums of money as shall be in proportion to the amount of work going through, or alternatively the amount of work that each man does. When there is repetition of movement of material I see no reason at all why such work should not be put into direct labour and put on to a piece work basis. It is only a question, to my mind, of whether we can afford to have the work so thoroughly time studied that payment by results would be safe.

I believe that the reason that this kind of work has not been put on piecework before, or to any great extent, has been the fear that it might cost more unless we spent considerable sums of money in a thorough time study. Such thorough time study could not take place unless we were assured that the conditions were likely to obtain for a fairly lengthy period, and this is the real snag because few factory managers can be assured that such conditions will remain stable for any length of time.

Incentive Schemes.

Of late years, however, there has been a tendency to believe that this side of the subject, *i.e.*, the proportion of our indirect labour, is best handled by providing some financial incentive either to that section of our staff who are supervising our indirect labour, or as an alternative, a financial incentive which shall not only include the supervisors, but also all of the indirect labour.

There are many schemes in force at the present time whereby such financial incentive has been provided. The subject, however, is too long and too involved to be dealt with here to night, but it is mentioned because it may have a definite bearing on our overheads in relation to our output. Before leaving the subject of incentives I would like to say that whenever one is thinking of the possibility

of installing such incentives, there are three points that should receive special attention. Considered broadly, any scheme of award to either the staff of a production department, or to the staff and personnel of a non-producing department, should be directed towards :—

First.—Encouraging the staff to do all in their power to bring up the efficiency of their department and thus reduce the amount of labour.

Secondly.—Should be so designed that all concerned will make efforts to limit the number of participants by reason of a desire for a larger share of the award, and

Thirdly.—Should see that the award would also tend towards reducing labour. This is best achieved by making the award vary with the ratio of the productive to the non-productive labour in the particular department. High ratio means high award.

Conclusion.

The whole question of overheads is a matter of vital importance to us, and that is my excuse for imposing on you as many of my random thoughts on overheads as was possible in the time at my disposal. Before I conclude, however, there is one more thought which must of necessity be dealt with and I would like to deal with this by first asking a question and then giving what I believe to be the answer. The question is : What can we as production engineers do to ease the burden of overheads ? Obviously, any attempt to answer such a question must be general. Since there are many expense items which are outside our control, clearly we can only influence a part, but we should, of necessity, be interested in the whole of the problem. There are, as I have said, many items outside our control, but there are many serious items which we can control within certain limits. There has been growing of late years a strong belief that production engineers should confine themselves to production problems solely, and I am not prepared to disagree with this belief providing always that we have a clear conception of what is a production problem. My idea of a production problem is the problem of making a piece of apparatus at such a price that our customer can afford to buy, and unless we as production engineers do definitely take some interest in the question of overheads, then quite possibly we might produce the work at a very quick rate and still have a cost that is outside the limits of our customer's purse.

My answer to the question of what can we as production engineers do to ease the burdens of overheads is as follows :—

We should cultivate a production mentality, and this mentality must embrace as one side of it a thorough understanding of all problems connected with overhead expenses. The first result that follows an inquiring mind is that of asking questions ; finding out

why this, and that, should happen. If we only show a little inquisitiveness on the question of expense burden of our own particular factory we shall soon begin to have a better understanding of what overheads mean. I do not want you to misunderstand me and think that I would have a production engineer pay too much attention to the work of the accountant, but I do want to emphasise that it is very necessary that he should know something of the work of the accountant. When you know something of this side of the problem you will be led by gentle stages to those points in your own department where you can manipulate both expense, labour, and material, so as to make savings. Your own particular savings may be small, but the sum total of a number of such efforts in any establishment would undoubtedly result in a material decrease in the expense burden.

What I want production engineers to do is to bring to the study of overhead expense burden the same type of mentality that is required for success in their job as a production engineer. I want them to so widen their horizon that they can see both overheads and production at the same time. In other words, I want them to train their mind along the parallel lines of overheads and production.

Discussion.

MR. S. CARLTON SMITH : At the commencement of this meeting I announced that Mr. Groocock had altered the title of his paper from "Overheads and Production," to "Random Thoughts on Overheads." I have good reason to believe that his primary object in making this modification to the title was to avoid the possibility of any semblance of posing as an authority on this subject, to elicit the views and experiences of members and to stimulate debate. One of the most direct ways of encouraging discussion is to disagree with the speaker. Unfortunately in this respect, I have to confess that I am heartily in agreement with nearly every word he has spoken. For purposes of debate, therefore, I single out the only two opinions in his address with which I disagree. With regard to the first, I so utterly disagree that I ask you all not to believe a word he says about it—and that is where he states that he knows very little about the subject. The second point is about salesmen. Mr. Groocock said something to the effect that he had no time for salesmen. As production engineers we may be closely tied down to our job and see or know little about their activities, but I do know that good salesmen are not only a most important adjunct to an industry but a most influential factor in the output required of the production engineer. An old friend of mine, who is managing director of a large engineering concern, says that he has a perpetual vacancy, and that is for a good salesman, and as fast as that vacancy is filled another vacancy thereby occurs. A good salesman can not only discover fields for development, but should stimulate and even create a demand for the products of industry.

MR. GROOCOCK : I still feel that I know very little about the interesting subject of costs, and the more you think about it the more you find something else you ought to know. With regard to salesmen—quite obviously we must have someone to sell, and, as your president pointed out, we want all our salesmen to be live wires, not only to come along and say they want something next week, but to tell us before-hand so that we can get out a sales budget. I believe that there are very few, not more than five per cent., of the engineering firms, that have such a thing as a sales budget. I know that this is a very low estimate, but they are generally firms in the motor trade, and this trade forms about 10 per cent. of the engineering in this country.

MR. REED : I should like to ask Mr. Groocock's opinion regarding making special tools in the tool room, and whether and when it is cheaper to buy them out or not. There are times in production when special tools and jigs are very urgently required and this should be explained and left to the discretion of the tool room foreman.

MR. GROOCOCK : With regard to the tool room, I agree with Mr. Reed. You must have the best service from the tool room, and if they are making standard tools it is wise to bring this matter up for review—it should always be under review. There is one thing a tool room has never been able to do and that is to make tool makers. I have been in business a few years now and there have never been enough tool makers.

MR. BEDFORD : There are one or two points I would like to raise. I notice that you have mentioned inspection as an overhead. I feel that inspection should be treated as a separate item in the made-up cost of the work—in some way as a labour charge. Inspection varies with the type of job. For instance with automatic machines you inspect five per cent. of the work. You get special apparatus made up by skilled labour, and inspection is a very small proportion of the cost of labour. You get other parts made up when you feel that a 100 per cent. inspection is necessary. And then you get parts made up in a works when inspection varies with the different operations. For these reasons, inspection should be charged as a cost to each operation. I would suggest that the management should get out a general budget for non-productive work under four heads : *Labouring*, *Maintenance*, *Millwrighting and Hardening*, and a certain sum should be alloted per week for each of these items, the management to watch that care is taken to work to these limits. I should also like to refer to the question of hand labour and Automatic machine labour for making bolts, and the system of working out overheads in proportion to the square ft. of area of floor space occupied for any given work or operation.

MR. GROOCOCK : I understand Mr. Bedford's point of view with regard to inspection. In some cases it is possible to consider inspection as somewhat distinct from overheads, and in cases when inspection can be charged as a percentage of the labour this should be done. But at other times inspection does have to be taken as overhead. With regard to automatic machines and working out overheads per square ft. of floor space, this would work out better for the automatic machines if sufficient work was at hand to keep the machines busy all the time, but it is usually a case of only having the machines in work for a few hours of the day.

MR. REED mentioned about a special reward system introduced some years ago in an engineering works, and showed how this system was applied. The improvement in results due to this system was amazing.

MR. GROOCOCK : I suggest that things must have been on a very poor footing before this took place, in order that they could start at the bottom.

MR. MCGUIRE : I would like to ask advice on two problems. My firm run a jobbing shop and also a department for selling large

quantities of raw material. One man may spend a few minutes in taking an order for raw material for £100 and in another instance he might spend half-an-hour getting an order for parts for the jobbing shop and the whole value of the order would only be about £10, but the whole of the overhead is put on the jobbing shop. How would you suggest proportioning the overheads out on two types like this ?

MR. GROOCOCK : Mr. McGuire has put forward one of the teasers and I don't think it really falls within our subject. There must, however, obviously be some system of allocation of sales overheads as well as for our shop and office overheads, and I would advise a study of the figures and frequencies to arrive at the best application for different businesses where conditions may vary considerably.

MR. O. CARLTON SMITH expressed appreciation of the vitality and practicability of the ideas presented by the lecturer and of his ability to marshal and present the crucial facts and the danger signals. He emphasised the necessity for really efficient time checking in order that the correct figure might be obtained for the direct labour on which the overhead percentage was based. One point, for example, was the necessity of taking account of all excess costs in labour due to an operator not being down to estimated time or rate allowed for an operation. Budgetary control, of some sort or other, was essential, and also a cost accountancy system by which the overhead burden recovered in sales could be balanced against the overhead burden incurred.

MR. REED : One point that has often occurred to me is, should interest on mortgage be considered as an overhead ?

MR. GROOCOCK : That is outside my department and is a matter for the directors to deal with. All I can say is that there should not be any mortgage, any more than there should be an overdraft.

MR. S. CARLTON SMITH : The subject of " overheads " is to-day becoming a science. A definition of science is the collection of proven facts, and procedure in accordance with the known data. The laws of science are remarkable for their exactness and immutability, of which one sees striking examples in astronomy, mensuration, mechanics, heat, physics and electricity, and the other branches of science. One is forced to wonder sometimes whether these various branches are not inter-related and correlated in some mysterious way so that in two differently classified branches the same laws may govern both. I was much impressed by an article which appeared in the technical press illustrating an application of this theory. The writer suggested that the curve of efficiency of production was identical with that of Kelvin's for the size of an electrical conductor. There was the initial capital cost of the conductor, the larger the conductor the greater the first expenditure and the standing charge to be carried on the cost of producing current.

On the other hand, the larger the conductor the lower the transmission losses due to current density so that there was a point, with one curve rising and the other falling, where the two lines intersected and that was the point of highest efficiency. Similarly in a works, for a given capacity of plant there was a corresponding output of highest efficiency and a proper relation of all standing charges and overheads. It is obvious that the cost per unit produced would be greater if the standing charges had to be spread over a less number than the ideal output, and if Kelvin's Law is applicable it is to be deduced that the cost per unit will also increase if a greater output is attempted than given by the number indicated by the maximum efficiency point, the losses in this case being caused by such items as increased tool and plant upkeep, breakdowns, fatigue, overtime and night rates, congestion of work and transport.

MR. GROOCOCK: Some of the problems in overheads and increased costs lend themselves to a purely practical solution, whilst others may only be mastered by examining and tabulating all the factors and finding a mathematical formula for the solution. It seems conceivable that you might have two vastly divergent problems dealing with totally different matters, but provided that the same factors applied to both the same mathematical formula or graph would apply.

MR. BROOMHEAD proposed a cordial vote of thanks to the speaker, and this was carried enthusiastically.

MECHANICAL AIDS FOR COLLECTION OF PRODUCTION DATA.

Address presented to the Institution, Birmingham Section, by F. G. Nash.

IT is only by reason of the little experience I have gained by being in close contact with different production engineers' jobs that I have any locus standi here to-night. I do not pretend to offer here any *general* conclusions regarding the problem of a production engineer's job. What I am about to do is to attempt to indicate *certain* lines along which some people have travelled in order that they could produce goods in an organised way. You must therefore excuse me if I subsequently demonstrate my remarks by reference to this kindly loaned Powers-Samas equipment: they are not the only vehicles by which such a laudable end may be reached; there are others.

Nevertheless machines are but machines after all, and behind those machines there always must stand the presiding genius—or, more often I think—devil. You know, gentlemen, we hear a lot of talk to-day about mechanisation and its benefits—this is because the accountant is only just beginning to wake up to the fact that he has been living 30 years behind the times—but you all know in your capacities as production engineers, that the ultimate production of *the* machine is dependent upon many factors outside of the machine itself—(accountants take a long time to find this out, by the way) factors such as accuracy and speed, with which the material upon which it is to work is provided. Send a steel sheet of incorrect gauge to a press and there is trouble; send wrong or incomplete data to a production engineer's office, and there is also trouble, but worse, for a production manager has been known to be sarcastic: sarcasm is lost upon a toggle press!

It is interesting to consider, too, the difficulties under which a production engineer labours. A manufacturing plant may be laid out to infallibly produce, say, X articles per week; its design, spacing, operation layouts, raw material, transport and so on may be expressly designed for those X articles per week; and yet, when it comes to the point it is sometimes found that only by continuous chasing and beautiful blasphemy that things can be kept moving. It is like trying to stuff an inner tube inside its cover; when it is in, it fits perfectly and does its job, but sometimes in getting it in we push here and it comes out there!

Indeed, I think it is too often overlooked that the production man is up against difficulties quite outside his control. Take suppliers. We can chase our stores and planning and progress departments, but it is difficult to chase suppliers—really. We are dependent upon our suppliers for goods at the right price, of the right quality, of course, but most important of all to us here—*at the right time*. If we base our output upon the assumption of Z steel castings from suppliers each week and they send Z — 100 (" Oh yes, the others are—coming along" ! ! !) we and our chiefs can tear our few hairs as much as we like, but it won't make any difference. Your production engineer is unable to go into the highways and byways and compel them to come in.

Yes, one of the difficult things about the job is, not so much that we are legislating production *by* machines, but that we are forced to control the hundred and one conflicting vagaries of those who feed the machines, and, of those whose duty it is to pass the production of the machines to the subsequent processes.

As an instance of this, I know a works which produces five main lines of articles with an average of 1,000 different parts in each. Now *all* of these parts move each day so that, in a week, 30,000 movements of parts must be controlled (1,500,000 per annum), and since 1,000 sets of articles are produced annually, the foregoing figures become—in terms of actual quantities—1,500 million per annum. Do not forget also that 90 per cent. of these pieces have to pass an average of 10 operators.

Now it is obvious that to control the production of such an organisation as this, it is not sufficient to feed one end of the factory with raw material and then hope for the best, as I am told some American manufacturers do not, what must be carefully controlled is, *the rate of flow of the material through the organisation :* all materials have a differential rate. For instance, some material is bought-out finished and passes, after its inspection on the receiving deck, direct to the erection bench ; other components arrive on the receiving decks in the form of raw materials, as iron ore, bar steel, sheet brass, etc., and must travel literally miles before they reach the erection benches.

Therefore, then, I consider any piece of material passes through the following five main categories :—

(1) It can be an order from the supplier.
(2) It can be delivered.
(3) It can be passed to the stores O.K. for use.
(4) It can be issued out of stores to production, and
(5) It can finally be incorporated into the finished product.

In addition to this aspect of the matter, there is also the labour cost side to be considered, and, in the case I have just instanced, attention has to be given by the management to the fact that the

labour costs of the operations upon 1,500 million parts per annum must be kept down to a specified figure. It is well known that unless a careful watch is kept on labour costs they have a tendency to rise rather than recede, but since the labour cost is a function of time it is possible, in the case I am mentioning, at least, to check up on the labour costs by carefully keeping the output above a specific minimum.

In any case, we are again brought back to the time question and the flow of the parts through the various manufacturing processes.

The problem is, therefore, how to efficiently and economically control (1) the *total* rate of flow, i.e., X completed pieces per day : and (2) the differential rate of flow, i.e., X component parts per day.

There is now one other specific instance of the intricacy of production control which, with your kind permission I should also like to give. It occurs at the works of some producers of extremely high class general engineering products, turbines—of all types and sizes, condensers—surface and water tube, deaerators, pumps,—centrifugal, high and silft and what not—Diesel and semi-Diesel engines, steam engines—high speed compounds ; and electrical apparatus such as D.C. machines, alternators with all the appropriate controlling gear. All of this equipment had to be produced as special jobs ; it is true that some of the pumps and semi-Diesels were capable of quantity production, but by far the larger part of the firm's output was special machinery made to firm's order. For instance, if a customer wanted the exhaust of his steam hammers to drive a turbine or if H. M. S. X and Y wanted special auxiliaries to run on phenomenal loads and in inaccessible bulkheads, our firm usually were asked to do the job. The amount of such varied orders as these passing through the shops gave pretty continuous employment to only about 1,500 men, and, as you see, the problem which was here forced upon the management as prices became lower and greater and greater workshop efficiency was demanded, was not so much the continuity of control of a large volume of articles, but a persistent supervision of the dates of the operations to be performed upon a comparatively few number of highly differing parts, so that the components of an order such as a turbine could all be infallibly focussed to a definite date of erection in the test bay.

Sometimes the process of manufacture, according to the nature of the mechanism, took two months, some twelve months : a set of pumping engines for an Egyptian dam might take two years. In such a concern the capital value of the work-in-progress was highly considerable, and this, to a large extent, had to be financed by the company ; moreover, the nature of the machines produced made it imperative that once the job had been started it was important that it should be got out of the way as soon as possible : an accumulation of enormous turbine baseplates, condenser sheets and pump

casings, produced, of course, in the shops a bad attack of indigestion —or perhaps I should say congestion. Certainly, though, it used to give some of us indigestion. Well, attention was carefully given to this problem and the production department organised a most excellent arrangement of documents and planning boards.

The proposal was that as each order was obtained and the delivery date had been agreed upon with the customer, the production department broke the order down into its component parts, decided which parts and which material were to be bought from suppliers—material such as say oil coolers, turbine blading, special steel castings, etc. They then produced material lists for the various departments—foundry, brass shop, smith shop, machine shop, etc. Additional to these material lists were operation sheets whereon the various operations (in hours) for each component and part were duly set forth, and such details were given as :—

(*a*) Shop where work was to be done. (*b*) Type of machine and tools to be employed. (*c*) Time allowed. (*d*) Next operation.

It would look as if this work involved much staff, etc. : actually it did certainly mean considerable technical work in planning, but the clerical work was largely reduced by mimeographing or dittoing common information such as job number, drawing number, etc., upon the whole of the operation sheets for any one part number, the varying information upon the individual operation sheets such as description of operation, time allowed, etc., had of course to be filled in by hand. Having thus achieved our plan for each job, the total hours allowed were added up and these, when appropriately edited and deducted from the delivery date, gave an approximate date or time by which the job should be started if it was to be ready by a certain date.

All went well, and as the various completed operation sheets filtered through from the shops the planning department flagged these appropriate operations off on their production boards. As I say, all went well ; and a marked improvement in the flow of work through the shops was noticed ; things were speeded up considerably. So much so that every now and then bad gluts occurred in the different departments : sometimes it was the iron foundry, sometimes the machine shop, sometimes the erection bays and the anomalous position occurred of overtime and night shifts in one department and short time in others. I always remember one striking clue which eventually put us on the right track : it was in connection with the machine which cut the double helical reduction gears for the turbines. These machines were fairly expensive, and we only boasted a couple of them, they were solely set up for machining the gears I have just mentioned, and all of these turbine gears had to pass under these cutters. They were veritable bottle-necks, but the flow of work down them could be as accurately measured

as water flowing down a Venture water-meter! The fact which led us to study these machines was that sometimes our turbines and alternators were coupled and erected on the test bay floor, and were merely awaiting the gearing. You can't roadtest a car without its gearcase, and neither could we test our large turbines without their gears; one can push an incomplete car into a convenient corner until the missing part arrives, but one cannot lose a 10,000 K.W. turbine with the same felicity.

Sometimes, to ease the work on our gear machines, we had to hurriedly send the gear blanks away for machining—to the sub-contractors' delight, no doubt, but to our sad loss. So we investigated our planning of turbine gears and of course we found that during the months of, say, January, February and March, though this period provided for a maximum of, say, X working hours on those machines, the amount of gear cutting work we were legislating for during that period for those machines turned out to be X plus 200 hours; it was the old story of valiantly endeavouring to coax a magnum quart from the imperial pint pot.

This then indicated to us that to attain our goal it was not sufficient to plan as we had been doing, we should have to go much deeper and plan by machine hours in the case of the machine shop, and man-hours in the case of the foundry, smithies, fitting and erecting shops. Indeed, the whole matter was looking pretty involved, and the management began to indicate that if we had to go into such detail then the days of profits were over, for any—which even in those times were faintly discernible—were almost certain to be swallowed up by the considerable increase in staff which would be necessitated. But production *was* to be controlled—with a big C—and so we had to get down to it.

I don't say that the way in which we finally achieved such great success is the only way, but it helped us and it may even give this very distinguished audience a new line of thought: certainly it may give your speaker a bad quarter of an hour when question time comes in the very near future! Now hitherto I have confined my remarks to two specific problems. I have ventured to do this because (1) I hate being indefinite upon such an occasion as this; a production engineer always wants to get away from vague generalities and down to non-ferrous, small, sharp broad headed nails—or brass tacks, and (2) the problem, if duly considered and understood, is always the handiest weapon with which to assail such brass tacks.

Moreover, the instances which I have ventured to indicate are, I think, at the opposite ends of a production engineer's diverse duties: one involves a control of a quantity-production job, and the other postulates a small but involved general engineering business; and the production engineer's functions lie somewhere in the

permutation and combinations between these two limits. Before I go on to briefly illustrate the methods by which the executives of the companies concerned eventually met and eased these somewhat troublesome structures which were necessary to their planning and production control, a word or so on the advantages and disadvantages of ordinary clerical systems of production control may not be out of place.

The oldest instrument of clerical labour is the pen ! And this—shall we say, primitive machine ?—coupled with an appropriate brain are together a pretty complete and efficient implement. For it can do what no machine can possibly do, it can interpret, weigh and consider, and make decision ; from the barest and most incomplete allusions it will grasp the extent of the whole picture. It can and does make bricks without straw : but because brains may vary, so also do the quantity and utility of the bricks produced fluctuate ; and therein lies the snag ! But, just consider the essential differences between the task of a machine tool and the task of a clerk with his pen. The machine tool deals with that which can be measured, demonstrated, and can otherwise be reducible to rule ; the latter has to deal with incomplete data, covert allusions, presupposed hypothesis and the hundred and one variations and mutations of written and verbal " instructions " (so called).

All this brings me back to those remarks I made at the opening of this talk wherein I endeavoured to indicate that one of the hardest of the production engineer's tasks was not so much the legislating of, but the administrating of, his output programmes. It is, for instance, one thing to legislate a prohibition law, it is quite a different matter to administer it. How then, can the production engineer's wishes and requirements regarding his output programmes be infallibly conveyed to the whirling cutters of his machine tools, to the busy benches of his assembly shops, and to the serried ranks of material bins in the stores ? That is the question. The answer, I think, is given by the engineer himself when he says he will apply those same sound principles of production to his office as he does in his workshop—he will, he says, eliminate as far as possible the human liability to error. He argues, and I think quite rightly, that if he, by machine methods, can turn out articles from his workshops all with tolerances and limits of mere thousandths of inches, why should he not be able to control the raw material deliveries, the inter-shop transfers, the stock requirements, etc., of those same articles, with similar machine-like precision and accuracy ? Therefore the engineer produced an " adding " machine :—a machine would add.

And since that date the sad lot of hundreds of individuals like myself has been to hawk around this invention—this machine tool—of the engineer and try and interest those clever accountants who ought to want it, but who up till recently rather hankered

after their ancient files—and pens. You can remember this when your accountants next tackle you over your really monstrous overhead charges, or some other minor matter !

As a matter of fact, though, the efforts of the production engineer himself to control his production may be classified into three distinct periods in the following way : (1) The pen and paper period ; then (2) the pin and flag interval ; and (3) the machine or millenium period.

I venture to suggest, that even as I speak, there are, in this otherwise very distinguished audience, many whose working lives are spent in the atmosphere of the waste paper period, or the kindergarten school ; I am afraid I shall pay for that remark, too, when question time comes, so, for the remaining time allotted to me I will now depict the really horrible lives spent by those efficient managers who cannot escape from machines even when they reach their own opulent and palatial offices !

Now from the works side of the story, it must always be borne in mind that in organising an office for productive control most of the documents which pass through it (and from which the engineer has to draw off the requisite data he needs)—such documents as time cards, stores requisitions, delivery notes, etc.—are being eagerly sought by the accountants' fellows ; and if these documents are held up over any length of time the latter immediately start chasing so that those accounting records such as payrolls, suppliers' accounts, costs and stores accounts may not be held up. All this means that the production control office have to rapidly extract such data as they require from the documents and then pass them on. This rapid extraction process gives rise to two snags, one is that it sometimes does not matter how many people are engaged to draw the data off, it yet cannot be done in time because not more than one person can work on one piece of paper at any one time ; and, secondly, when working at high speed, clerical errors are bound to occur. And hence the mere adding machine—which is, after all, but a machine pen—does not entirely fulfil the requirements.

So now for the solution of the large and detailed production job I mentioned at the outset of these few remarks ! Here you will remember the problem was not, as in the second case, to control a comparatively small number of large and intricate parts, but to control a vast number of simple pieces—for erection into their final product on a line-assembly system ; the difference perhaps between harrassing a mountain torrent and a placid Thames. If I may continue the metaphor, the burines in each case were based upon the same principle—the punched card.

In the specific case with which I am dealing it was decided to

punch cards for handling the materials at each of the five main flow-points, that is to say :—

		Goods are punched from :
(1)	" Goods Ordered "	Copies of Buyers Orders.
(2)	" Goods Received "	Goods Received Notes.
(3)	" Delivery to Stores " ...	Inspector's Certificates from the Receiving Office.
(4)	" Material Issues "	Stores Requisitions.
(5)	" Finished Stores "	Progress Reports.

The data appearing on each of the foregoing sets of documents were therefore accommodated upon an appropriately designed Powers-Samas card which has five main quantity " fields " or columns. The descriptive data such as piece number, etc., is accommodated in a series of columns which are in common positions on all of the five sets of cards. At the inception of the system (at the beginning of a financial year, by the way), a master card—a buff one—was punched for each piece number, showing the production position for each piece at that date, and a series of pigeon holes were erected in the production office for each piece number into which pigeon holes the master cards were filed. During the first day of the new financial year, detail cards were punched for the movements of the material, these cards being : *The Goods Orders Cards ; Delivery to Stores Cards, etc.* If during the day there were any pieces scrapped on the receiving deck, or in the shops, red cards—known as deduction cards—were punched for them.

At night all of the cards punched during the day were amalgamated with the master cards and the whole pack of cards mechanically sorted on piece number and then tabulated. The result is that on the morning of the second day the following information for each piece number is revealed :—

(1) How many, say, crankshafts have been ordered.
(2) ,, ,, are outstanding on order.
(3) ,, ,, have been delivered.
(4) ,, ,, have passed inspection.
(5) ,, ,, are available for immediate use.
(6) ,, ,, have been issued from stores to production.
(7) ,, ,, remain in stock.
(8) ,, ,, are in work in progress.
(9) ,, ,, have been used upon completed articles.

—all this, I repeat, for each piece number.

From the tabulations, new master cards are punched, and the whole process is repeated the following night when the next day's cards have been punched and sorted. Is it not obvious that the foregoing data provides the completest information possible within a minimum of time ? It was found, as time went on and matters were tightened up, that it was not then necessary to tabulate for

the whole of the pieces numbers, but only for those which were behind schedule. This means that, instead of immediately tabulating the whole of the cards after the sorting process, the cards are further subsorted to article number. Now, it is known by this firm's management that, if the organisation is functioning correctly, it is possible to say on any day the actual numerical sequence number of the last article which should be produced on that day. By this I mean that if last night the last article completed was numbered 25,000 (this number, by the way, must not be confused with the articles part or parts number) and if to-day 750 have been turned out then 25,750 will be the number of to-day's last article. And, further, if the management had, in the programme, legislated for 760 articles to be produced to-day, then the number of to-day's last article should have been 25,760 and not 25,750. Therefore, if the Powers-Samas cards are automatically sorted by article number, all of those cards which are found to be punched with details *above* that number are within the programme and are O.K. Those *under* the number are offenders and represent those pieces which are not up to schedule.

So now these offending cards alone are mechanically extracted and each morning a tabulation of them is handed to the departments concerned and they are thus informed of those pieces, the non-production of which, unless immediately rectified, will be likely to hold up output in the course of the next 24 hours.

And therein, I venture to hint, lies a considerable advantage, in the method used, which is that those things which are getting behind (for all sorts of very good reasons—specially hard castings, machine tool breakdowns, etc.), are known immediately and can be put right before their actual absence causes a hold up. Production engineers do not want history, they need current facts.

Now in the case of the second firm, you will remember we were dealing with a small number of engineering products, the modus operandi adopted was this. When the planning department planned the operations and times allowed of the various parts, the data thus evolved was noted upon operation cards and these cards themselves were immediately punched with those details. Among such information punched into the cards was included the following: (1) Date to be started by. (2) Date required by. (3) Time allowed. (4) Shop (and in certain cases machine number).

The operation cards which had been made out each day were, each day, mechanically sorted by the Powers-Samas sorter in "date required by." They were then tabulated on the automatic tabulator printer and the number of hours allowed aggregated for each delivery date. Thus, say to-day, on December 16th, we shall know the extent of the machine, or man hours, we have added to the amount of work which was required of the heavy machine shop during any week ending March 16th, 1932. This total we should

enter upon the heavy machine shop master " time allowed" schedule, so that to-morrow the planning man could observe therefrom how many spare hours there were during that week, and he would be prevented, when the time allowed total reached the maximum available hours of that department for that period, from going on blindly planning work for that shop in that period.

The cards which produced this valuable information have now begun a long journey. Immediately after the tabulating process I have just described, they are re-sorted to " date to be started by." In this order they are filed so that as the time for the first operations draws near, the cards will be extracted, sorted by drawing and part number, and then issued to the shops.

When the job is actually in progress, the employee will record his time thereon and so soon as it is finished, the operation card will be returned to the time office, where the time taken, value and pieces completed, etc., will be further punched into the card. A tabulation of these cards immediately reveals the efficiency of the shops by disclosing the time saved and lost, and this tabulation of the cards—which, it should be noted, is also a record of completed operation—is sent to the progress and planning departments.

Lastly the cards are passed to the wages and costs department who, by appropriate sorting and tabulating of the same cards, produce both the wages sheets and the job costs.

It is interesting to note that throughout this long series of clerical operations, everybody is working from the same basic data—a punched card—and so, if the holes are correctly punched, all the records must be accurate and in the completest agreement with each other. In fact, this accuracy is one of the points which is much commended. If the alternative methods are used there is a liability to error every time anybody draws information from the operation and planning card ; whereas if the data is punched and verified, completest accuracy results.

Now Mr. Chairman and Gentlemen, I have presented two problems with their two solutions. I won't answer for the problems, but I am perfectly clear that the solutions are as clear as mud ! It cannot be otherwise ; how can I or anyone in a few moments explain in unparalleled and limpid diction solutions which took months to effect and perfect. Realising my inadequacy and accurately forecasting the fact that any remarks of mine would rather obscure than clarify such a topic as the use of machines as applied to production control, one of your members suggested that he could place at my disposal this evening his own set of Powers-Samas machines so that those machines themselves could discourse to you. You therefore observe the machines, ready to answer the questions that I am going to put to them, and, I would add, it is

not so much to their answers that I should direct your kind attention, as to the rapid and accurate way in which they are yielded.

For the whole thesis of my remarks to-night may be summed up in these words "If production is to be controlled, such control, to be effective, must be instantaneous, accurate and rationally based upon reliable data, the production of which data is in its turn best achieved by those same methods used by the engineer in his shops—the machine."

Discussion.

Mr. J. A. Hannay said that when it was first suggested that the Section should have a lecture of this sort, the committee came to the conclusion that it would be very interesting if they could get Mr. Nash to speak to them and describe some of these machines. During the last five years, some of the machines had been installed in Birmingham, and without giving away any secrets, he could say that an installation capable of turning out 150 chassis per week had increased its capacity to 1,500 per week without the clerical staff being increased, except for a few girls using punches, in addition to about £7,000 worth of machines.

It was found impossible to get the information up to date to allow the operator, the record office and production department to know exactly where they were unless there was some rapid mechanical means of solving the problem. He prophesied that in 20 years time all records would be kept mechanically. Although these machines were not adaptable right away, yet by concentration and adaptation it had been arranged so that they could handle the problem. The one great advantage they had given was that by 8 o'clock each morning, when the works opened, there could be an exact statement in any department telling their position up to the time of closing the works the night before. There was no waiting for everybody to go through their various accounts—things were all done for them. Further, the girls punching the cards get very expert, and at half-past five, leave their machines with a stack of punched cards, after which a few young men commence working, and by 9 or 10 o'clock, the tabulating and sorting of data is done. The shop superintendents do not have to search round to find out what the position is ; once a week a large tabulation comes to them showing exactly where they stand on the operations they have to make ; the amount of material they have in hand to be delivered, and also a column showing the amount that has been ordered.

The only snag in these machines, in his opinion, was the price. He thought they should be on a production basis. He admitted that, except for large firms, an installation was impossible, although he had noticed that though, last year, a quantity of something like two million cards were used, it really only cost the expense of two or three junior clerks' wages. The storekeeper, for instance, could have a tabulation showing what the firm is going to produce in a current week, and it would tell him what his position is, and he will know what he has to issue out. In future works would have to be controlled by some mechanical means such as these.

Mr. Hannay then described an experiment carried out a short time ago by a junior member of the staff, wherein a design was

made and a complete schedule drawing office list giving all the operations required for that particular model. A card was punched for every piece, and it was decided in what batches these pieces would be given out. The cards were then arranged for the whole lot and distributed round the works. Instructions were given to the store men to issue material exactly as stated on the cards, and before issuing they were put through the tabulator. The result was that the works had no requisitions to write for material but simply had to hand these cards in, as they wanted material, to the storekeeper. It was quite automatic ! When the job was done, all these cards were collected and run through the tabulator, and a comparison made, but where there were irregular issues and the storekeeper had to issue material to make these up, it would be shown on another column. These were then sent through a tabulator and this showed the original cards and what had gone through extra. This was, he thought, the last word in the way of getting production through the shop, and he would venture to develop the idea. He pictured ten thousand employees, some of them working on the same job week in week out, some doing two or three hours on one job and a few hours on another. As soon as the man had done his job, an inspector would survey it, a card would be punched with the time, the rate and everything put on it, and dropped into a box, where it would lie until the end of the week. Then the cards would be collected, put through the sorter, and filed, and so build up one complete record of the time of every job, price, wages payable to the man doing the job, etc. As production engineers, beside spending their time on high production machines, they needed to turn their attention to this problem, of keeping in touch with costs. In doing ordinary clerical work, we had to put up with mistakes. These machines were adapted now to verify work. In any case, in the event of a mistake, the machine added on a million, or something of that sort—there was no putting one or two odd figures on. The machines were being used to better purpose in this country than in any other part of the world, and if we put our attention to the business of production control we should be able to more than hold our own.

MR. NASH said that as regards price of equipment, they were a British firm, and there was only one way in which they could decrease their price—that was, for people to buy the machines. They were not producing these machines in the same way that Messrs. Heinz produced foodstuffs, and they could not have lowest production on that job. 85 per cent. of the work was handwork, and while they were, he thought, the only company which had not increased its price on account of the gold standard difficulty, there was no indication at the moment that they were going to reduce it. With regard to Mr. Hannay's comment on accuracy, it was encouraging

for him to hear such a comment. He himself knew it, but when he said so, people took it with a pinch of salt. The machines really were accurate, and as Mr. Hannay had said, should anything go wrong it did not slyly add on one, but a whole unit, which was 99,999, so that if a man in the works had a pay ticket of £99,999 he would think something was wrong.

Mr. Geo. Williams said that in listening to Mr. Nash he was reminded of the book and film "Metropolis," in which a genius worked out a great system of control of labour and machinery in such a way that by pushing a button the workmen came to their jobs ; machines called out their duties ; production never failed, and everything was wonderful, but the forces of nature rebelled and rushing waters came in and engulfed them. Mr. Williams said he did not suggest, however, that we should get to that stage. He had been interested in the illustration of how the amount of material available was shown. It would be appreciated by production engineers that the production manager could prime himself, before going into the works, with all necessary information. Another point Mr. Nash had mentioned was the question of forecasting production. We wanted to know much more in advance what we were going to do. If, for example, it was necessary to produce castings from two hundred patterns per week, and it was necessary to produce castings in excess of that quantity so as to compensate for scrap, should there be any, and also scrap which might be found during the machining operations, sufficient castings would have to be produced to ensure that the production line was not held up. Arrangements would also have to be made to ensure that the production manager was getting his correct supplies of material. There were other interesting mechanical aids to production, such as the machines for calculating ratios and percentages, which were quite useful, and also a modification of the machine for recording production at the various points.

Mr. Nash said he hardly knew what to say to Mr. Williams in respect of his ethical charges. Being somewhat of a philosopher, the question "Where are we going ?" had already given him thought. As to what would be the position in a thousand years hence, he could only suggest that we should only need to work an hour a day. The difficulty then, to his mind, was not so much one under which they would be labouring when at work, but how to spend leisure time. If we did not know how to spend our leisure time at the moment, what were we going to do when we had eight spare hours a day ? With regard to Mr. Williams' comment on forecasting production, in one particular instance the position re-solved itself, thus : They had legislated for coremaking and moulding in terms of coremaking and moulding hours, knowing how long it would take to make cores and do mouldings for castings ; they punched

cards for these different jobs, showing the total time involved in making the different cores, and in making mouldings; and sorted these cards and put them through the tabulator. They then said "We have 250 people in our foundry, therefore if each man works 48 hours, the whole moulding time available is X. According to our time table we have X moulding hours available, therefore we must either work overtime or put on more men." Foundry work was not easy, particularly where it was complicated by the special machines so much in use now. With regard to other machines he had already mentioned that there were others, but the machines under discussion were not calculating but tabulating machines. In ordinary commercial practice, there was a lot of calculating to be done, for instance on wages. If the time up to date in respect of a job number was wanted, it was necessary to take many papers and go through them, and if you wanted the data under job number, the pieces of paper had to be taken and gone through again on job number, whereas, if the information was once punched and verified, the process of job costing and wages figures was merely sorting and tabulation. These machines were not only used in engineering works. Their range was so widening that frankly he did not know where it was going to end. Plant of this kind was at that moment in the throes of doing the census, and within fifty feet of that very building tabulators were preparing statistics in regard to tuberculosis and other diseases.

MR. TAYLOR asked how Mr. Nash would determine the adjustment between supplier and final requirements, taking into account scrap?

MR. NASH replied that this was done quite simply. The programme legislated for so many articles, and so many articles were sent. Those of them that were faulty were punched on red scrap cards, and if there was any difference or irregularity in their figures, these scrap cards were tabulated in piece number order. The buyer's office every morning received tabulations showing the number of pieces which had been scrapped in respect of each category of material, with the production date, so that the buyer could get into touch with the suppliers and straighten it out from that point of view. With regard to the cumulative figures, it followed a book-keeping transaction. When further delivery was made by the suppliers to replace that "debit" card, it remained with the piece number, so that, as a matter of fact, at the end of the financial year one could go to one of the pigeon holes provided for each piece number, say No. 1A4016, and get all the cards out. The bottom card would be a master card made at the beginning of the financial year, and all the others on top would be transactions which had taken place during that period. Out of these cards would be found

many of the red ones, and many of the green, which were the further supplies of material coming in.

MR. WARE said that members of the Institution would be interested to hear something of the electrical means which were employed on the various tabulators.

MR. NASH said that the card was designed for the job. The difficulties of the job were discussed and as far as possible the card was designed to meet them. The production engineer next said " Having got our card designed, we now want a schedule like this." " It is now our job," said Mr. Nash, " to make the machine do that, and it is done by a ' special component ' inside the machine." The machine was not in any way (except just for the motor) an electrical operation, but entirely mechanical throughout. The cards came in at the bottom part, and there were holes, pins stuck through, and it was by means of these projections that the printing and adding part of the machine worked. There was then the special component, which connected up every possible position on the card to every possible position in the adding machine. That evening they might be dealing with production ; to-morrow they might be dealing with prices, or job costing. Another " box " was provided, designed to handle the job card, and the production box was taken out and the new one put in.

MR. GODDARD said he had had experience of the machines under discussion, and asked Mr. Nash what would happen in the event of it being found necessary to insert a further operation into the operation cards, between existing operations ? It appeared to him that at the present time there was no chance of another operation number being put in front, and that carrying an operation one further was the big problem of costing systems. He had suggested that a prefix might be used, such as 015 or 014, but the department which handled such matters said it was impossible to have a prefix. Could there not be an indexing arrangement to prevent all those operations having to be set back on account of one or two extra operations ?

MR. NASH replied that, with regard to the specific point raised by Mr. Goddard, he was not quite clear at the moment as to why it could not be done, and he would have to accept Mr. Goddard's statement that it could not. The tabulator was designed to customers' requirements. Some people wanted pounds, shillings and pence, some wanted decimal points. It might have been that when that particular machine was built, the point was overlooked, and when the day came, in actual practice it was found that there was not a position available for the particular prefix. But in nine cases out of ten, those little points could generally be overcome, usually by having a spare position somewhere. In the case in point, it might be got over by having a prefix.

A VISITOR said he might possibly give the solution to the problem. The firm with whom he was connected had, in fact, overcome the same trouble with the operation numbers. With machining operations three columns were allowed for the operation numbers, all over the works. The operations naturally started with No. 1 and reached to more than 60. It was therefore decided that all machining operations would be numbered from 1 to 60. Immediately another operation was applied to any piece, that operation was numbered from 61 upwards. These operations did not go into more than three figures. When they wanted to bring in a strange operation, as Mr. Goddard's illustration, it was decided that they should go up to, say, 600, and would put in that operation and call it 601, and if another operation came in, 602, until such time as the whole lay-out could be revised.

A suggestion was made by another speaker that they should make the cardinal numbers 10-20-30 and so on, and if another operation had to be put in it should be 11-12 or 13.

MR. NASH replied that if the speaker meant they should use the units column, Mr. Goddard had suggested that not only was the tens column in operation, but the units as well.

MR. W. G. GROOCOCK, in proposing a vote of thanks to Mr. Nash, said that this paper emphasised what he had mentioned on many previous occasions, that we were in the machine age. One of the questions that had arisen out of the paper was that high productivity would leave us with a good deal of spare time. Personally, that was a question that did not worry him, because he never had had any, and he did not think he ever would have time to spare. He reminded members that two years ago in his presidential address he had mentioned " the possibility of replacing manual work in the office, or in the recording of data that is necessary, by the probability of doing such work by machines. Greater savings could often be made here by the introduction of equipment costing £100 into the office, than would be effected in the machine shop by the introduction of £10,000 worth of machinery."

The machine under discussion was the kind of machine he had in mind when making the above statement. It was a wonderful machine and when he saw similar machines ten years ago in America, he had quite a difficulty in getting away from them. The more he studied this kind of equipment, however, the more he felt that they were tied up very largely with quantity manufacture. Mr. Nash had mentioned two specific cases, one of which was for turbine blades. The question he had raised was that of a bottle-neck, and this question of restriction of output at certain parts of our works was one that every branch of industry had to face. It is quite true that where this machine could be installed, such restriction of flow, or the possibility of such restriction of flow, could be realised in time

to take some action. Suppose we do know where our output will be restricted by lack of material, or by shortage of machines, there might still be a period of from one week to one month where kamming would take place. That was where the machine would still leave something for human knowledge and experience to cope with. As time went on and we had the opportunity of learning to get the full use out of such machines, we should be constantly finding further uses for them. Personally he agreed with Mr. Hannay that the great disadvantage at the present time about this machine was its price. This Mr. Nash had explained as being due to their manufacture on a small quantity basis, and he had explained that there was a possibility that if we could all persuade our directors to order these machines so that larger quantities could be made, then we would be able to get the machines at lower prices.

The vote of thanks was cordially adopted.

MR. NASH, in responding, pointed out that while an installation such as Mr. Hannay had in mind might cost £7,000, a small installation of one sorter, one tabulator and one punch, would not cost half that amount, probably about £2,300, and that further, there were other ways of getting it, for instance by hire purchase. This was a little more than renting, but in five years the machine would become the property of the purchaser, while the payment would not be more than the salaries of a few juniors. He did not want the £7,000 idea to obscure the issue; the machines were not so expensive as that; they were not more expensive than ordinary adding machines while doing very much more work.

EFFECT OF STRESS CONCENTRATION ON STRENGTH OF MACHINE PARTS.

By Harry Shaw, Grad.I.P.E.

IS it generally realised, we wonder, that an absolutely rigid body, subjected to stress at an absolutely sharp corner, is infinitely weak? But no body is absolutely rigid, nor any mechanically-produced corner absolutely sharp, and therefore bodies in practice have always some degree of strength, however sharp be the junctions between surfaces, for the concentration of the stress cannot then be infinite.

Do not breaking machines depend for success upon increasing the stress concentration? Would one expect the bar in a machine to break if instead of a sharp nick, the bar were merely reduced in section by a groove or a recess? It would certainly bend before it broke. A nicked bar is very much weaker than a bar of the "nick" section. No wonder, then, that cracks in driving axles of locomotives seem to start at the corners of keyways produced, no doubt, by customary means, square cornered cutters.

To get a round-cornered keyway is well worth while, even at the expense of reducing the axle's cross-sectional area by a deeper keyway. The same principle applies to the shoulders of shafts. Sharp corners are incipient cracks, always. Where the stresses are severe, shoulders should always be radiused out, even if the radius undercuts the shoulder. The firm whose practice it is, in shafts to be ground, to start grinding with a thin radius wheel, is worth following by those who realise how hard on a grinding wheel is a radiused corner in the work. The firm make radiusing an independent operation carried out in a simple grinding machine. The radius wheel is sunk in to leave a slight step, which the parallel grinding wheel may remove entirely or leave part as a slight witness as circumstances of finish demand.